Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia - Social and Behavioral Sciences 54 (2012) 637 – 645

Procedia
Social and Behavioral Sciences

EWGT 2012

15th meeting of the EURO Working Group on Transportation

A proposal of indicators for evaluation of the urban space for pedestrians and cyclists in access to mass transit station

Fernanda B. Monteiro,Vânia B.G. Campos*

Instituto Militar de Engenharia, Praça General Tiburcio 80, Praia Vermelha, 22290-270, Rio de Janeiro, Brasil

Abstract

This work presents indicators for the evaluation of urban spaces elements considering pedestrian and cyclist access to mass transit stations. The indicators are proposed from a literature review and from the result of a survey implemented on two subway stations in Rio de Janeiro. The survey intends to understand the difficulties to access the subway station by bicycle or on foot but it also addresses the subways user profiles. Indicators were selected to represent aspects of the urban environment and infrastructure characteristics of mass transit station access.

Keywords: pedestrian, cyclist, mass transit

1. Introduction

Mass transport systems integration to non-motorized transport is the basis for sustainable mobility. Therefore, the entire environment around stations of mass transit systems (BRT, tramway, subway, commuter train) should be evaluated, aiming to attract the pedestrians and cyclist users. Among these elements are sidewalks, pathways, crossings, signage, lighting, and landscaping that should be planned in order to promote the use of urban spaces for pedestrians and cyclists around the mass transit stations.

The succeed of this integrated system demands the necessity to analyze the various aspects associated with non-motorized transport modes, identifying factors that make people choose to walk and cycle in their trips for working or studying, and the characteristics of the urban environment that can encourage these modes of transport.

In this context, it is also necessary to know the profile of those who make use of non-motorized transport to access a mass transit station. The knowledge of the users profile enables to evaluate and develop strategies to be implemented in order to attract a potential demand for non-motorized transport around public transit stations.

Therefore, in this work, it is proposed indicators for evaluation of the elements of urban space for walking and cycling access to mass transit stations. These indicators are based on a literature review and on a survey applied

* Corresponding author. Tel.: +55-21-38204186 ; fax: +55-21-87439403.
E-mail address: vania@ime.eb.br

1877-0428 doi:10.1016/j.sbspro.2012.09.781

to users in some subway stations in Rio de Janeiro city. The selected indicators represent aspects of the urban environment and of access infrastructure around the stations, as well as the appropriate criteria for the analysis. It is considered that these indicators will enable the evaluation of urban spaces in order to integrate non-motorized modes with mass transport and effectively promote sustainable mobility in urban areas. Besides, these indicators can subsidize the development of strategies to be implemented in order to attract a potential demand for non-motorized transport around public transit stations**.**

This papers is structured in five sections, first section comprehend this introduction. The literature review about the characteristics of urban spaces for pedestrians and cyclists is presented on second section. The third section presents the survey applied on subway stations in Rio de Janeiro and the forth section comprehends the proposed indicators. Finally, the conclusion is shown on fifth section.

2. Literature Review

The spaces for the traffic of pedestrians and cyclists should be planned and designed so as to maximize their safety and comfort during their diary trips. The quality of non-motorize transportation includes the continuity of paths, the attractiveness and convenience of routes, subtle elements that involve several factors: the distance to be traveled, the slope of the track, the conditions of sidewalks, the straightness of the route and any other factor to facilitate walking.

But the main difficulty in dealing with issues related to the quality of urban spaces is the definition of instruments that can evaluate the adequacy of sidewalks and bike paths conditions. In literature there are several important variables that define methodologies for assessing these spaces. For assessing pedestrian space, Fruin (1971a, 1971b) has based on the methodology for roadway level service. To characterize the service level of the sidewalk, he quantified the pedestrian facility by studying parameters such as: human anatomy, field of view, comfortable distance between bodies depending on the relationship to the other person, walking down stairs and psychological perception of urban space. Years later, in 1985, the reference manual on practical design of roads, the Highway Capacity Manual - HCM (TRB, 1985) was supplemented with a guide for the pedestrian to elaborate the design of sidewalks, based on Fruin (1971a) methodology.

In 90 years, Sarkar (1995) tried to make sidewalks safe for urban intersections and user groups considered vulnerable. Already Dixon (1996) sought to evaluate the spaces allocated to pedestrians on roadways. These works, in addition to analyzing volume and capacity, as proposed in HCM; include qualitative measures to characterize some subjective variables, such as security, safety, comfort, convenience, continuity, system coherence and attractiveness.

The methodologies of Khisty (1995) and Ferreira and Sanches (2001) have in common the objective of evaluate the qualitative elements of pedestrian spaces, from the users perspective. In these methods the evaluation are based on subjective variables such as visual attractiveness, comfort, system continuity, safety and security.

In the case of cyclists, most of the methods are based on the work of Landis (1994), Davis (1987), Sorton and Walsh (1994), Epperson (1994) and Landis et al. (1997). Until 1980 the factors commonly used to quantify the quality of service offered to cyclists were: speed, freedom to maneuver, traffic interruptions, comfort, convenience and safety (Epperson, 1994). After 1980, some works have been developed based on the conditions of the roads (Epperson, 1994; Sorton and Walsh, 1994; Dixon, 1996; Landis et al., 1997) using the following evaluation criteria: traffic volume, path width, speed limit, pavement condition and location of the pathway (Turner et al., 1997). Only with the methods of Hunter et al. (1995) and Wang and Nihan (2004) analysis of accident risk has been considered.

Tables 1 and 2 summarize the parameters for analysis of pedestrian and cyclist spaces used by the authors mentioned above. These parameters were grouped in six issues related to the urban infrastructure and environment characteristics.

Table 1 –Summary of variables used for analyses of pedestrian spaces

ISSUES	*VARIABLES*	*REFERENCES*
DENSITY	Population density, residential density, households, employment density, pedestrian flow	Cervero & Kochelman, 1967; Leslie et all, 2006;HCM (TRB, 2000); Fruin, 1984; Mori e Tsukaguchi, 1987
DIVERSITY OF LAND USE	Land use parceling, proximity of residence and services, convenience, connectivity from origin to destination point	Cervero & Kochelman, 1967; Leslie et all, 2006; Fruin, 1984; Khisty, 1995; Gallin, 2001
URBAN DESIGN	Road width; traffic flow separation between the modes, visual design, system coherence, conflict between pedestrians and vehicles, accessibility to public transport, urban ambiance, urban form.	Fruin, 1984; Sarkar, 1995; Khisty, 1995; Dixon, 1996;Tori e Tsukaguchi, 1987; Antunes, 2010
FACILITIES FOR PEDESTRIANS	Overall width of the sidewalk; Effective width of the sidewalk, pavement type, rate barriers; rate of green area; Number of parked vehicles, obstructions at intersections; Attractiveness, Comfort, Continuity of the system.	Mori e Tsukaguchi, 1987; Antunes, 2010; Sarkar, 1995; Dixon, 1996; Ferreira e Sanches, 2001; HCM (TRB, 2000); Khisty, 1995.
SAFETY AND SECURITY	Possibility of falls and injuries; Perception of Security, Personal Security.	Ferreira e Sanches, 2001; Sarkar, 1995; Khisty, 1995
CHARACTERISTICS OF PEDESTRIANS	Speed of Walking	HCM (TRB, 2000); Fruin, 1984

3. Survey of subway users

A survey on two subways stations was realized to identify the characteristics of users who usually go to the station on foot or by bicycle, but also to understand why others do not use this travel mode. The subway stations are in Rio de Janeiro, Brazil. Studies developed by the subway system operator indicate that 65% of subway users walk to the stations while only 0.2% cycle. Recently, bike parking was implemented in some stations but it was observed that only in some of these stations the bike parking was well accepted.

A form was prepared for the inquiry, with the main objective to point the profile of those who make use of non-motorized transport to reach a mass transit station. The survey was performed during the rush hour, in the morning, one of the busiest periods.

The stations are located on Ipanema and Pavuna, the end of two subway lines. Ipanema station is a median and high class neighborhood and Pavuna station is a median and low class location. It is worthy noted that despite Ipanema is a neighborhood of high income, there are some slums nearby the subway station.

100 people were interviewed in Ipanema from 7:00 am to 10:00 am, the morning rush hour. Most of them were female and has between 21 and 30 years old. A large percentage of people has university degree. Their average income is between A2 and D classes, by Brazilian economical metrics (A2 class range from US$ 3,680 to US$ 6,230 and D class range from US$ 340 to US$708 per month), with D class majority.

Most of Ipanema users interviewed said they preferred to walk due the proximity of the station from their homes.

Subway integrated bus system is the second preferred way to access the station, used mostly by people who come from a distant neighborhood (approximately 30km from the subway station). There was no bicycle user during that survey period. The bike parking at this station has low usage during this survey.

Table 2 –Summary of variables used for the analyses of cyclist spaces

ISSUES	*VARIABLES*	*REFERENCES*
DENSITY	Population density, residential density, employment density, average daily volume of bicycles	Cervero & Kochelman, 1967; Botma, 1995;Epperson e Davis, 1994 .
DIVERSITY OF LAND USE	Urban zoning, characteristics of residential density and services within the influence area.	Cervero & Kochelman, 1967; Leslie et all, 2006.
URBAN DESIGN	Number of traffic lanes of the cycling road, lane width outside; location factors of the cycling road; Number of vehicular access.	Epperson and Davis, 1994; Landis et all, 1997; HCM (TRB, 2000)
FACILITIES FOR CYCLIST	Pavement conditions; width of the cycling road; Infrastructure for cyclists; Conflict; maintenance of the roads.	Epperson and Davis, 1994; Landis et all, 1997; Sorton e Wash, 1994; Dixon, 1996, Landis et all, 1997
SAFETY AND SECURITY	Speed limit, speed of vehicles; differential speed between vehicles, service level of the road	Epperson e Davis, 1994; Landis et all, 1997; Sorton & Wash, 1994; Dixon, 1996, Landis et all, 1997;HCM (TRB, 2000)
CHARACTERISTICS OF PEDESTRIANS	Frequency of events	Botma, 1995

In Pavuna station, 160 people were interviewed on the station platform and on the access to bicycle parking. The interview was performed at the same time of Ipanema, between 7:30 am to 11:30 am. In this station, the users majority was male and has between 21 and 30 years old. Most of them with college degree and economically rated as D class.

Tables 3 and 4 present a summary of the first analysis made from the Ipanema and Pavuna subway survey. The results enable to identify some characteristics of the users and their difficulties of walking or biking to the stations, as well as the characteristics of those people that do not use these ways of transportation.

It was observed that most respondents uses bus to reach the station due the distance between their homes and the station, distances greater than 50 km. The second option most used was cycling. Many people choose this option, even though the distant from their home and lacking of infrastructure, to save money that otherwise would be spend in travel costs. These users are satisfied with the bike parking, which was 80% occupied during survey.

Analyzing data from the survey in subway stations, is possible to observe that users are willing to walk or bike a certain distance from their homes to the stations. Besides, important parameters for analysis of urban spaces for pedestrians and cyclists were noted.

If the stations are located in residential or commercial density zones, most users go on foot to reach their destination. When the area surrounding the station does not have this characteristics, their users have to overcome greater distances to get to the station, preferring to use a motorized mode of transport (some of them can cycle but but only in extreme cases to reduce transportation costs). High residential density has the presence of multifamily buildings, such as Ipanema Station neighborhood, where the percentage of pedestrians was much greater than in other stations. Otherwise, in Pavuna station neighborhood, single-family houses are prevalent (low density), leading people to travel long distances, preferring to use bus or bicycle.

It was also noted at Ipanema neighborhood, that along the street with the residential buildings, there are a large number of shops; these characteristics turn walk a very attractive experience and pedestrians travel great

distances without perceived. In places where land use is less diversified, the act of walk can become tiring and unpleasant.

Table 3 – Survey results on Ipanema and Pavuna stations

Characteristics		Ipanema	Pavuna
GENDER	Male	42 %	60%
	Female	50%	40%
AGE	10 to 20 years old	7 %	12%
	21 to 30years old	30 %	31%
	31 to 40 years old	23 %	23%
	41 to 50years old	17 %	17%
	51 to 60 years old	16 %	10%
	61 to 70 years old	7 %	6%
	71 to 80 years old	0 %	1%
EDUCATIONAL LEVEL	Elementary School	9 %	23%
	High School	29 %	55%
	undergraduate incomplete	5 %	13%
	undergraduate	57%	9 %
INCOME	A1 - US$ 6, 222 or more	6 %	0%
	A2 - US$ 3, 683 to US$ 6, 222	15%	1%
	B1 - US$ 2, 667 to US$ 3, 683	18 %	1%
	B2 - US$ 1, 417 to US$ 2,667	16 %	5%
	C - US$ 708 to US$ 1, 417	18 %	21%
	D - US$ 340 to US$ 708	19%	43%
	E - US$ 142 to US$ 340	8 %	29%
TRANSPORTATION MODE USED TO ACCESS THE STATION	On foot	57 %	11%
	Bicycle	0 %	23%
	Ride	2%	3%
	Van	2 %	4%
	Car	1 %	1 %
	Taxi	0 %	1 %
	Bus	2 %	53%
	Bus integration system	36 %	4%
TRAVEL TIME TO THE STATION	0 to 3 minutes	4 %	0%
	4 to 6 minutes	23 %	1 %
	7 to 10minutes	36 %	6%
	11 to 15 minutes	14 %	19%
	16 to 20 minutes	5 %	23%
	21 to 30 minutes	4 %	24%
	31 to 40 minutes	6 %	17%
	41 to 50 minutes	3 %	9%
	51 to 60 minutes	1 %	1%
	More than 60 minutes	4 %	1%

Table 4 (continuation of table 3) - Survey results on Ipanema and Pavuna stations

Characteristics		Ipanema	Pavuna
DIFFICULTIES TO ACCESS THE STATION BY FOOT	Sidewalk poor conditions (holes, puddles, etc)	10 %	9 %
	Lack of safe crossings and signaling	3 %	2 %
	Public insecurity (assaults)	5 %	4 %
	Lack of Lighting	0 %	0 %
	Physical disability	3 %	3 %
	Distance to station	10 %	72 %
	None	41%	6 %
	Others	20 %	4 %
DIFFICULTIES TO ACCESS THE STATION BY BICYCLE	Cycle way poor conditions (holes,puddles, etc)	3%	11%
	Public insecurity (assaults)	10 %	6 %
	Cannot take it on the bus or subway	3 %	0 %
	Lack of cycle ways	15 %	20 %
	Lack of proper bicycle park	4 %	2 %
	Lack of shower and dresser room at Station	12 %	2 %
	Dangerous traffic	7 %	7 %
	Do not have a bicycle	5 %	9 %
	Physical disability	5 %	8 %
	Distance to station	20 %	26 %
	None	2 %	2 %
	Others	14%	7 %

The survey shows that the travel distance is the major problem for pedestrians to go to the station. Elements of urban design could contribute to "shorten" the distance to be traveled, for example: smaller blocks allow a better alternative routes or paths to a destination. A pleasant walk, with the presence of landscaping, trees and gardens, wide sidewalks, regular pavement and presence of shops on the streets could make the travel distance shorter.

The physical conditions of the sidewalk pavement were another point raised by users as a major impediment to go on foot (mainly for women). Also, dirty sidewalks, potholes and puddles can make walking uncomfortable and dangerous, especially for children and seniors.

The security issue was also highlighted, not only because of uneven sidewalks, but the lack of safe crossings for pedestrians with signaling and lack of bike lanes in the city, where, in some places, the only alternative for the cyclist is to share the same space with cars and buses, which makes the trip stressful, exhausting and extremely dangerous.

From the survey it could be seen that to analyze an urban area many issues must be verified, from the original urban design to maintenance of infrastructure and facilities.

4. Proposal of indicators

Indicators can synthesize complex information, facilitating the understanding and monitoring the progress of different transportation system, therefore they can be used for the analysis of urban spaces in the access to transit stations.

From the methods, presented on section 2 and based on the survey results, presented on section 3, seven issues were selected as those with major influence in the subway users' decision to access the station, which might be used to evaluate urban spaces. The seven issues are:

Density - higher residential and employment buildings density, in a particular region, especially near the stations of public transportation, favors the inclination of people to reach their final destinations or to the transport stations either by foot or bicycle.

Diversity of land use - different land use is a factor that greatly favors the daily movement of people, whether for service, trade, leisure, and so on, short distances from their residences to the final destination, which can be made on foot or by bicycle.

Urban Design - all urban elements that make the tour more pleaser and that will encourage the movement of pedestrians and cyclists, these elements are: the arrangement of blocks of a city, crossings, adequate sidewalks, the presence of public transport with bus stops, routes and cycle lanes etc.

Facilities for pedestrians and cyclists - aspects of comfort and urban ambience, with respect to the physical characteristics of the sidewalks and bike lanes as the quality of pavement, slope , steps, street lighting, tree planting, barriers, street architecture, a series factors that favor or not favor the movement of pedestrians and cyclists.

Accessibility and mobility - are all necessary elements in the direction to promote safe mobility of persons with disabilities or reduced mobility, they are: ramps, tactile pavement, audible and visual signs.

Safety - in regard facilities and operational conditions of streets that makes the pedestrian or cyclists travels more safety: signalized crossings, level crossings that will minimize the conflicts between vehicles, pedestrians and cyclists, traffic flow and speed on the road.

Security – is related to aspects of public safety and sense of protection, such as the existence of policing, and areas of "natural surveillance" that means areas with many people in movement and good visibility of the space.

Table 5 – Pedestrian space: Proposal Indicators and Criteria

URBAN USE	
INDICATORS	**CRITERIA**
Density	Population density (hab/ha)
	Residential density (homes/ha)
Diversity	Number of shops within the surrounding area
	Dissimilarity of shops (number of types)
URBAN DESIGN	
INDICATORS	**CRITERIA**
Facilities for Pedestrians	Presence of sidewalks on both sides of the street
	Effective width of the sidewalk
	Regularity of sidewalk pavement
	Presence of trees
	Street lighting
Accessibility and Mobility	Access ramps on the curb at pedestrian crossings
	Sidewalk with tactile floor
	Visual and audible signaling at pedestrian crossings
	Gradient of the sidewalk
Safety	Safe pedestrian crossings
Security	Police on the streets

From the definition of the issues to be considered, it was defined a set of indicators based on the features mentioned above. The following analysis is divided in two different parts. The first part includes indicators related to urban use aspects. The second part includes indicators related to urban design aspects; this one comprehends the physical characteristics of the paths and conditions of the surrounding areas. The proposed indicators and the criteria used to measure them are shown in the tables 5 and 6.

Some of the attributes are given the value 0 (zero) or 1(one), indicating the existence or not. Others, such as the regularity of pavement, have the measure defined as the percentage of the segment (of the sidewalk or bike path) on favorable terms.

Table 6 – Cycle space: Proposal Indicators and Criteria

URBAN USE	
INDICATORS	CRITERIA
Density	Population density (hab/ha)
	Residential density (homes/ha)
Diversity	Number of shops within the surrounding area
	Dissimilarity of shops (number of types)
URBAN DESIGN	
INDICATORS	CRITERIA
Facilities for Pedestrians	Presence of bicycle lanes
	Effective lane width the bicycle lanes
	Regularity of lane pavement
	Presence of trees
	Street lighting
Accessibility and Mobility	Access ramps on the curb at intersections and near stairways
	Gradient of the bicycle lanes
Safety	Safe crossings
	Distance from de vehicle flow
	Flow vehicle density
Security	Police on the streets near the bicycle lanes

5. Conclusions

In this study, it was observed that there are several means to analyze the spaces for pedestrians and cyclists. This analysis allows identifying indicators for understand and measure the spaces around mass transit stations and to use them to monitory the proximity of these stations. The intent of this monitoring is to improve pedestrians and cyclists access to mass transport stations encouraging them to use non motorized transport for this purpose.

The analysis presented in this work can be used as a tool to enhance safety and comfort of pedestrians and cyclists during their diary trips and increase the attractiveness of mass transit system. Besides, the observation of the indicators proposed in this work can lead to cities improvements increasing life quality and providing better urban mobility.

Computer tools, like GIS software (ArcGIS), enable to represent the values of each indicator on maps. These tools and the provided survey data can evaluate the distances travelled by the stations users and identifies the radius of attractiveness of walking trips around them. Finally, using the proposed indicators/criteria, it is possible to make a spatial analysis of walking paths within that radius around some stations.

Acknowledgements

The authors acknowledge CNPq, Brazilian government institution, which has supported this research.

References

Davis, J. (1987) ,Bicycle Safety Evaluation. Auburn University, Auburn.

Dixon, L. B. (1996), Bicycle and pedestrian level-of-service performance measures and standards for congestion management systems. *Transportation Research Record* 1538, 1-9.

Epperson, B. (1994) Evaluating suitability of roadways for bicycle use: toward a cycling level of service standard. *Transportation Research Record* 1438, 9-16.

Ferreira, M. A.; Sanches, S. P. (2001) Índice de Qualidade das Calçadas – IQC. Revista dos Transportes Públicos 91, 47-60.

Fruin, J. (1971a) Designing for pedestrians: a level-of-service concept. Highway Research Record

Fruin, J. (1971b) Pedestrian planning and design. Metropolitan Association of Urban Designers and Environmental Planners.

Fruin, J. J. ;Benz G. (1984). "Pedestrian time-space concept for analyzing corners and crosswalks." *Transportation Research Record* 959, Transportation Research Board

Hunter, W.; Wayne, E.; Stutts, J. (1995) Bicycle-motor vehicle crash types: the early 1990s. *Transportation Research Record* 1502, 68-74.

Khisty, C. J. (1995) Evaluation of pedestrian facilities: beyond the Level-of-Service concept. *Transportation Research Record* 1438, 45–50.

Landis, B. (1994) Bicycle Intersection Hazard Score: a Theoretical Model. *Transportation Research Record* 1438, 3-8.

Landis, B. W. (1997); Vattikuti, V. R.; Brannick, M. T. Real-time human perceptions: toward a bicycle level of service. *Transportation Research Record* 1578, 119-126.

Sarkar, S. (1995) Evaluation of safety for pedestrians at macro and microlevels in urban areas. *Transportation Research Record* 1502, 105-118.

Sorton, A.; Walsh, T. (1994) Bicycle stress level as a tool to evaluate urban and suburban bicycle compatibility. *Transportation Research Record*, 1438 17-24.

TRB (1985) Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., EUA.

TRB (2000) Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., EUA.

Turner, S.; Shafer, C.; Stewart, W. (1997) Bicycle Suitability Criteria: Literature Review and State-ofthe Practice Survey. Texas Transportation Institute, Dallas, TX, EUA.

Wang, Y.; Nihan L. (2004) Estimating the risk of collisions between bicycles and motor vehicles at signalized intersections. Accident Analysis and Prevention 36, 313-321..